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THE TREATMENT OF WOUNDS

AS BASED ON

EVOLUTIONARY LAWS

PITFIELD MITCHELL

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THE TREATMENT OF WOUNDS

AS BASED ON

EVOLUTIONARY LAWS.

THE PROPERTY OF THE N. YORK HOSPITAL.

C. PITFIELD MITCHELL,

MEMBER OF THE ROYAL COLLEGE OF SURGEONS, ETC.

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"Leaving our rudeness and irregular course,
Stoop low within those bounds we have o'erlooked:
And calmly run on in obedience.
. . . . . New flight:
And happy newness, that intends old right."

KING JOHN, Act V. Sc. 4.

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PREFACE.

THE argument as here submitted to the judgment of my *confrères* was originally intended for contribution to periodical literature. The widely felt interest in the standpoint from which the discussion is conducted, and the pressing necessity for a scientific settlement of the questions involved, are chief among the considerations that have urged me to make the paper obtainable in this form.

C. P. M.

THE

TREATMENT OF WOUNDS AS BASED ON EVOLUTIONARY LAWS.

IN a short essay published in the *New York Medical Journal* for September, 1882, I endeavored to find in the Spencerian doctrine of evolution the foundation of a satisfactory theory to guide us in the treatment of such wounds as are inflicted in the more common operations of surgery.

That a further development is needed of this important branch of the surgeon's art is sufficiently attested by the declining popularity of the system introduced by Prof. Lister, and by the daily acceptance and abandonment of "new antiseptics" and "methods."

When there is absent any approach to unanimity either additional data are wanted or a better co-ordination is required of those already ascertained. In the present instance there are adequate reasons for suspecting a want rather of the latter kind. That the only desideratum is an amplification of facts is very improbable of phenomena so common, so accessible to observation, and so obtrusive by their bearing on immediate human interests as those concerned in the healing of wounds. Any attempt, therefore, to bring into relation with one another and with established laws those truths which experience has demonstrated may be approved for its seasonableness.

In the article referred to, I strove to effect in part this

affiliation, and I propose now to take up the argument afresh, for two reasons: the application to practice of the principles advanced is not there considered with that fulness demanded by the general interest and importance of this aspect of the subject; and since the essay was published decisive evidence has appeared supporting its capital conclusions.

Let us begin with a statement of these conclusions, then examine their credentials, and, finally, considering them as guides to practice, suggest a conforming treatment.

Inasmuch as the ensuing discussion will be occupied only with a special class of wounds, and the functional relations of the tissues to the *outer* environment, the reader is asked to carry with him the understanding that the argument at all times refers to cases in which the following conditions are constants:—the vitality of the tissues is normal, and no defect is present in the means for maintaining this vitality, *i.e.*, there is no defect either of quantity or quality of the material exchanges required for life and the function of repair—the *inner* environment is natural. The destruction of anatomical elements is supposed to be limited to the immediate effects of the primary injury—as in the case of a simple incised wound caused by the surgeon's knife. The remaining conditions, hygienic and other—it would be superfluous to specify them—are such as would be customarily considered auspicious for healing by direct union.

It will be recognized that the totality of conditions enumerated above are those obtaining in practice in a large majority of surgically-inflicted wounds.

The laws of natural selection, adaptation, and heredity, enable us to predicate the following categorical truths of the changes of function and structure required for the union of wounds: that such changes are essentially physiological, and adaptations of the organism to its conditions; that wounded tissues open to the external investing forces are naturally adapted to an average atmosphere, if the consecutive physiological processes have not been converted into pathological processes; that such tissues are not naturally adapted to outer

forces of adventitious origin—dirt, chemical and mechanical agents used in surgical practice—hence these forces tend to be perturbative of those co-ordinated chemical and physical actions by which cicatricial tissue is wrought; and, lastly, that the juices exuding in consequence of the solution of continuity are endowed with a specialized function—the protection of the cells they cover from injurious agencies.

The statement that reparative processes are essentially physiological might be taken as conceded, were it not that much modern practice still tacitly asserts the contrary.

The use of exorcising dressings implies a misconception as to the very nature of the vital operations we are considering. This misconception arises from mentally fusing the integrative and disintegrative actions which go on in wounds, and from failing to clearly perceive the causative phenomena—internal in the organism and external in the environment—to which these actions must invariably stand related.

The distinctions are most easily made in the little-complicated cases of incised wounds healing by first intention under normal—not factitious—conditions. The *disintegration* of tissue is here directly caused by the force which divides the histological particles, and ceases with the closure of vessels. With the glazing of the exudative plasma—the wound is open to the atmosphere—the *integrative* stage begins, and, if the surfaces lie in apposition, union results without further functional or structural disorder. It is extremely important to seize the fact thus brought out that, in the absence of perturbations other than the primary mechanical one, the series of changes setting in with the drying of the plasma are a series of *physiological* changes.

The vital forces by which this union is accomplished may, as elsewhere shown,* be usefully regarded as extrinsic functions of the injured parts, made permanent in the course of evolution, and mainly physical consequences of the newly-imposed conditions.

* An Evolution Aspect of the Healing of Wounds, New York Medical Journal, September, 1882.

In wounds where the sequence of changes thus outlined is broken by purulent discharges, sloughing, and the formation of granulations, there is in every case a corresponding break in the sequence of incident forces. These correspondences we shall discuss particularly later on. The object now is to clarify ideas as to the nature of the changes thus determined. In this endeavor we shall be aided by conceiving them as fulfilments of the laws of organic evolution and dissolution.

The first law formulates the progressive integration, the passage from homogeneity to heterogeneity, from simplicity to complexity, and from generality to speciality of function and structure.

The second law expresses the reverse process, the disintegration of function and structure, the passage from heterogeneity to homogeneity, from complexity to simplicity, and from speciality to generality. Though not co-extensive, the changes in the one case are physiological, in the other pathological.

Plainly, reparative processes in wounds conform to the law of evolution, beginning with an effusion of simple, undifferentiated, generalized plasma, there are developed indifferent cells, and finally relatively complex and specialized vascular, granulation, and connective tissues and functions and structures are reintegrated.*

The law of dissolution† is exemplified in sloughing and suppuration; the specialized, complex, multiform cells constituting combined structures, are converted, under the influence of disorganizing forces, to relatively general, simple, uniform pus or slough, and structures and functions are disintegrated. Doubtless from the frequent co-existence in wounds of these

* In the organization of cicatricial tissue the exudative plasma appears to serve a mechanical purpose; the embryonic vessels and connective tissue cells are said to develop in its fibrinous meshes like plants upon a trellis. On Sponge Grafting, by D. J. Hamilton, M.B., F.R.S.E., Edinburgh Medical Journal, November, 1881.

† Other illustrations from pathology of the law of dissolution may be found in Diseases of the Nervous System, by James Ross, M.D., vols. i. and ii., in the writings of Dr. Hughlings-Jackson, and in an article reprinted from the Medical Times and Gazette in the Popular Science Monthly, March, 1883.

two orders of changes, we have come to regard them as in some way co-operative. But by no sort of modification can an analytical process be concurrent with a synthetical process; to the extent that there is suppuration there is either arrest of normal function—in the present case reparative action—or, the functional derangement being carried further, disintegration and death of tissue; and if there is subsequent restoration of function and structure, the forces concerned reside in the uninjured parts.*

Thus rendered, the foregoing laws help, I think, to give definiteness to our views of the particular changes engaging our attention. That they state, in a very generalized form, real phases of these changes might be further shown by expanding the illustrations dynamically. It might be made evident, on the one hand, that with the integration of matter—development of tissue—there is a concomitant dissipation of motion; and, on the other hand, that with the disintegration of matter—dissolution of tissue—there is a concomitant absorption of motion; † organic evolution displaying an increase in the relative movements of wholes and a decrease in the relative movements of parts, and dissolution the reverse; a retrocession "from the motions of large masses to the motions of smaller masses, and from the motions of smaller masses to the motions of compound molecules, and from the motions of compound molecules to the motions of simple molecules." But expatiation beyond this—not necessary for us—would imperil the coherence of our argument. We may, however, pause for a moment to mark that when the sequent phenomena formulated as the law of organic dissolution are taken as a *re*volution of the sequences formulated as the law of organic

* A study of the intimate phenomena of inflammation leads Dr. Burdon Sanderson to insist "that the resolution of an inflammation means either that the temporarily arrested processes of normal life simply go on again, or, if the process have proceeded to its ultimate issue—death of the affected part—and what has been destroyed has to be repaired, not (as we used to think) by a continuation of the morbid process, but simply by the restitution of the normal condition." Lumleian Lectures on Inflammation, 1883.

† See Spencer's First Principles.

evolution, the constancy of pus as a product of dissimilar morbific conditions becomes much less incomprehensible. In a forthcoming paper I hope to look more narrowly into the nature of this phenomenon.

We have now to sustain the second proposition, which purports that a normal atmosphere cannot overthrow in the absence of other efficient forces the physiological changes sequential to traumatic injury. Proof of two kinds is available. It is a necessary inference from the conditions of existence, and is placed beyond the pale of questionable fact by published records of surgical experience and experimental investigation.

If we know the uniformities in the environment of any species, we can infer the corresponding adaptations of function and structure in that species; life being possible for the individual and the race only by the continuous adjustment of internal forces (functions) to external forces. Comprehending the succession of individuals forming man's ancestry, the atmosphere being an absolutely constant element of the conditions of external wounds, it becomes self-evident that without the organization of a functional harmony between the exposed structures and the medium in contact with them, the functional and structural variations which constitute reparative processes could never have become established. While the air was competent to break down tissues unprotected by the skin, the evolution of constructive changes was manifestly impossible. As I have already pointed out, "natural selection would take a large share in this evolutionary process. Animals whose wounds were not repaired would strive in the struggle for existence under a heavy disability. The non-union of muscles torn and limbs broken during encounters with prey and enemies would lead to incapacity for further encounters, and a dying off without issue; while others whose injuries were repaired would escape the direct hinderances and indirect dangers to life entailed by unhealed wounds, and would reproduce their kind."

Therefore, by selective action, by the immediate adjustment

of the physiological forces—direct adaptation—and by inheritance of the adaptations thus consummated there must ultimately result a type of blood and tissue whose chemical and physical constitution must enable them to withstand the impact of ordinary or average atmospheric forces.

This conclusion, subversive of much current belief, is not invalidated because the exposure of the internal tissues to the atmosphere is fortuitous. With the lower animals, from whom we inherit all that is fundamental of our molecular and histological organization, wounds are penalties to be incurred for the privilege of living, and are among the commonest incidents of our own lives.

So much for the deductive argument, which by some will be held discredited because it is deductive, and by many of small moment, being so dissonant from accepted teaching, though the teaching of unrationalized experience. Happily, however, there are verifying and unimpugnable facts to secure the endorsement needed to give a more scientific warrant for our methods of treating wounds.

It would be easy to choose from publicly expressed professional opinion, from fragmentary records of practice, and from our own experience, ample testimony sustaining the point we are called upon to establish; but in view of its importance we must confine ourselves to evidence which can neither be assailed nor ignored. Such has been furnished by Dr. Borland, Kilmarnock, Scotland,* and by Mr. Lawson Tait, Birmingham, England.† The services of these surgeons have supplied an instalment of data that must be marked off, in the directness and perspicuity of their significations, from all similar contributions to the subject under discussion. We shall have occasion at another place to refer to the details of the means employed, and to the actual figures of the results obtained by Dr. Borland and Mr. Lawson Tait. The present purpose is satisfied

* Ten Years' Surgery in Kilmarnock Infirmary, by Dr. McVail, British Medical Journal, July 23, 1881.

† One Hundred Consecutive Cases of Ovariotomy Performed without any of the Listerian Details, British Medical Journal, October 28, 1882.

in the coincidence that the systems of treatment practised are alike in the wilful disregard of Prof. Lister's doctrine, which assumes the contrary of the point for which we are contending, and in the unparalleled excellence of the results yielded. In both cases the influence upon the tissues of the organic and inorganic constituents of the atmosphere is in no way interfered with, and in both cases the statistical results surpass in a remarkable degree comparable results obtained under the preventive measures peculiar to the system of Prof. Lister. Now whatever the actual determining causes of those results, whatever the kind and quantity of the factors at work, we are permitted, nay, we are compelled to draw from the coincidence one indefeasible conclusion.

If, having given the greatest freedom of action to the agents hypothetically capable of initiating destructive changes, wounds not only healed, but healed more successfully than under all other and opposite principles of treatment, we must say that by virtue of their inherent properties the tissues were proof against the prevailing atmospheric conditions.*

But we are not restricted to this piece of *a posteriori* evidence, sufficing in itself as it may be, and so germane as it is to the purpose of our contention; experiment affords not less convincing proof.

By Prof. Lister ("Proceedings of the International Medical Congress, 1881") we are told, "as recent experiments had shown, serum, clear or bloody, is a very poor soil, for the development of germs from contact with air-dust and blood-clots are still more sterile; indeed, it is very difficult to make them grow or develop at all unless diluted with water."

And Prof. Burdon Sanderson (loc. cit.), making good the

* In the annual report of the Kilmarnock Infirmary for the year 1882, kindly sent to me by Dr. McVail, I find the following statements: "During the year, thirty-five operations were performed. . . . No case arose of pyæmia, septicæmia, erysipelas, or hospital gangrene. It is now upward of four and a half years since any such mishap occurred in the institution."

Of the three deaths in Mr. Lawson Tait's one hundred cases, the causes assigned are accidental suffocation in one, and venous thrombosis starting from the pedicle in two cases.

proposition that "no organisms endowed with inflammation—producing, phlogogenic particles, exist in the atmosphere or in the ordinary aqueous liquids with which our bodies come into contact," observes that "these supposed delinquents may be brought into contact with living tissues of all kinds, without producing any local disturbance. . . . As regards the air, one method, which appears to me to be very conclusive, consists in passing large quantities of air through the living tissues. In the rabbit, the subcutaneous tissue may be kept distended for days by frequently renewed injections of unpurified air, without producing any inflammation; nor is the effect more serious if the same tissue be ventilated by a continuous current of the same air for a number of hours, even when that air is derived from a *post mortem* theatre; whence it seems clear that so far as the tissue is concerned air is tolerably harmless, for by this mode of ventilating a tissue floating matter can scarcely fail to be deposited." *

Thus, without advancing, as we could, other facts and arguments equally trustworthy and cogent, we shall take it that we are confirmed in the conclusion to which the general doctrine of evolution commits us, that healthy tissues and secretions are self-protected against the morbific forces of the average atmosphere.

We may turn now to the fourth and last of the propositions with which we set out, the third proposition can be more conveniently dealt with afterward.

Again we must hold in view the general conditions ever obtaining with wounds throughout the later period of man's evolution. The first effect of any mechanical division of muscular and vascular structures is an exudation of the fluid parts upon the separated surfaces. If the injury is external, the skin no longer affording to the delicate underlying tissues that protection against outer forces which is one of its most important functions, the performance of this duty will be thrown

* See similarly positive and concurring remarks by Dr. William Roberts, F.R.S., quoted at page 131 of The Treatment of Wounds, by Sampson Gamgee, F.R.C.S.

upon the effused fluids. Being in direct contact with the external environment, they must early undergo physical and chemical transformations adapting them to the uniformly-present forces of this environment according to the laws of adaptation, natural selection, and heredity.

Attention was called in the earlier essay to the probability that drying by evaporation is one of the physical processes by which this greater chemical stability is given to the exuded blastema. The preservative effects of desiccation upon albuminous bodies is a trite fact to ordinary observers, and is explained on the physical principle that whatever diminishes the contained motion of a body—its molecular motion or kinetic molecular energy—gives fixity to the arrangements of its units, rendering more difficult either decompositions or recompositions.

Remembering, then, that for countless generations the order of events in wounds has been as above described—the exudation of the fluid parts and their immediate subjection to environing forces, we shall not hesitate to see in this exudative plasma, especially when inspissated, a peculiar fitness for sheltering the less stable protoplasm of the cells beneath. And the inference is strengthened by the following pointed testimony. The method of treatment after amputations and similar operations—by which Dr. Borland obtained the remarkable results already quoted, has the exceptional features that no chemical agent whatever is applied to the tissues, thereby insuring the molecular integrity of the effused lymph; while its inspissation is secured by allowing the flaps to remain exposed for a sufficient length of time to the action of the air.

It is not contended that Dr. Borland's success is thus accounted for, but it is contended that these procedures have probably been contributive, and that the validity of the above deduction and the facts in unison warrant assent to the proposition "that the juices exuding in consequence of the solution of continuity are endowed with a specialized function—the protection of the cells they cover from injurious agencies."

It remains to substantiate the third proposition: this will

introduce us to the ultimate purpose of the argument—the application to the treatment of wounds of the truths exposed.

By the statement that internal structures are not naturally adapted to casual and extraneous influences, the implication is that all chemical or mechanical agents other than those commonly present in the conditions of wounds—present in the conditions of wounds throughout past time—will tend to set up disintegrative changes in opposition to the integrative changes which would ensue in their absence. We say there will be present this *tendency*, unnatural conditions are, of course, not necessarily destructive of the physiological balance, for the forces may be so moderate in their quantities and intensities, and may have such chemical and physical relations to the tissues, that the latter are sufficiently stable to bear the collision—there will be an immediate functional adjustment. If, as we understand the teaching of Mr. Spencer, the static and dynamic attributes of an organism are the products of forces acting upon it in the environment, and of forces reacting in the organism upon the environment, ancestrally and individually considered, then every specific function, or physiological action furthering the interests of the whole, is possible only under the conditions imposed by the conditions of its evolution, that is, under moderate deviations from an average of the conditions to which we say it is organically fitted.

Whether the structure be an organ or a tissue, its appointed service in the economy cannot be performed unless the natural conditions of its life are more or less rigorously satisfied. Let, for example, the forces beating internally upon the skin, in the shape of nutrient fluids and nervous energy, undergo extreme changes in any direction; or let those beating upon it externally in the shape of light and heat, chemical, electrical, and mechanical forces, also undergo extreme changes in any direction, and the effect will be, with other things equal, * an extreme change in the correlated functional activities; the

* The qualifications are, roughly, the chemical and physical relations of the structures to the new incident forces and special individual adaptations.

balanced molecular movements which constitute the life of cutaneous tissue as such will be thrown into disorder.

That there are average conditions to be subscribed to for the healthful action of every whole is indisputable. But it is not less indisputable of every organ, of every tissue, and of every cell. Now, as we have said, these conditions are imposed by the conditions of their evolution in the race, and of their development in the individual as separate entities.* Hence, that the physiological life may be maintained of structures undergoing repair, there must be maintained the average incidence of the forces that have conditioned during evolutional eras the birth, growth, and development of cicatricial tissue, and if this average incidence is not maintained, the tendency will be for physiological action to pass into pathological action.

The doctrine of evolution requires that there shall be established relations between ourselves and the outer world. Whatever conditions are absolute, inconstant, or accidental in the surroundings shall be met in the *average* of the species by organic adjustments that are absolute, inconstant, or accidental. But the only absolute set of external actions conditioning the tissues when they are wounded is the atmosphere, and since its component forces are variable at different times and places, we anticipate adjustments to a *mean* atmosphere.

Hygienic laws are inductive confirmations. All sanitary effort directed toward moderating extremes in the aggregate of influences encompassing us implies the healthfulness of means, which is another way of saying that average organisms are adapted to average conditions. By the provisos of the argument the tissues whose adaptations we are considering are average tissues.

We may infer, then, that the heterogeneous substances connoted by the word "dirt," and the artificial chemical agents of the methods of treatment in vogue, are not constituents of the natural conditions of reparative processes in wounds. From their nature, and the infrequency and inconstancy of their in-

* As far as it is possible to consider separately units whose cycles of changes are dependent on the cyclical changes of other units.

cidence, we do not look for physiological adjustments in the tissues. They are therefore unnatural, and being unnatural we assume that they will not be conducive to union. Of course —to forestall a possible criticism—when morbid processes have once been induced, it will be required for the restoration of normal processes to change the conditions, and the change most expedient may be unnatural. To re-establish healthy action in a putrescent wound irrigation with antiseptic solutions may be a *conditio sine qua non*. It is needless to again remind the reader that we are speaking of those most common cases—belonging to the largest class of surgically-inflicted wounds—where the reparative processes are in equilibrium *ab initio*.

The rationality of our knowledge of the deviations from a standard of healthful activity in any organ or tissue—its pathology—depends upon the completeness of our knowledge of the conditions or laws of its normal life—its physiology. But the relations of the body and its members to natural external environments are as much a part of their physiology as are their relations to one another, with which latter class of relations Physiology is most frequently occupied. And so with the relations of the body and its members to unnatural environments as a part of their pathology, which is fully recognized. Physiology and Pathology both indeed increase in breadth and largely in utility with our ability thus to pass from the internal dynamic change to the corresponding external dynamic change. Therefore a rational pathology of the healing of wounds subsists on a more or less complete physiology of the healing of wounds. But the latter is incomplete, and seriously incomplete, when no reference is made to those normal and fixed relations—the organized adaptations—of wounded tissues to external conditions that have arisen during evolution.

With the amplified knowledge of them set forth in the preceding pages and the essay they are intended to supplement, we are prepared to pass in review the forces met with in common practice, and known inferentially and *a posteriori* to be detrimental to the genesis and organization of reparative tissue.

These prejudicial agencies are of two kinds, mechanical and chemical. Of the first are blood-clots, drainage-tubes, ligatures, sutures, dressings and manipulations of the tissues; of the second are chemical substances used in prophylaxis and therapeusis, dirt (by this conventional phrase anything out of place on wounds is understood) and chemical bodies resulting from the decomposition of exudations.

The mechanical agencies are unfavorable to healing by intercepting the conjunction of surfaces, by interfering with the nutrition of cells, and so causing the formation of devitalized products, which, undergoing secondary decomposition, may give rise to new chemical compounds, in their turn capable of setting up new functional and structural disorder.*

The chemical agencies are unfavorable to healing also in a direct and indirect manner. Directly, by deflecting the normal chemical exchanges of the tissues, and indirectly by generating morbid exudations.

Thus are comprehended the common causes of the non-union of wounds and the sources of septicæmia and pyæmia. There is a gathering consensus of opinion, and a daily converging evidence in support of it, that the less specific "surgical diseases" are always derivative morbid changes; that they are among the terminals of a series of pathological transformations. It is at once in harmony with the principles of biology, with the general and special facts of pathology, and with the teachings of antiseptic surgery, that the beginning of the series is a perversion of the normal processes of life by the action of forces that are cognizable and tractable. Under the stress of ordinary chemical and physical actions the internal molecular forces which hold together the relatively unstable elements of repairing tissues are subdued, and disintegration and

* "The exudation of a normal inflammation is not infective. Whenever an inflammation becomes infective it owes that property to chemical change in the exuded liquid of which the presence of microzymes is a necessary condition. Conversely, septic organisms which are infective owe this infectiveness to the exudative soil in which they have grown." Prof. Burdon Sanderson, loc. cit. See the evidence put forward to establish this proposition.

degradation of structure are the consequences. The degraded elements being no longer co-ordinate parts of the living body, are still less resistant than the organized tissues into which they were previously compounded, and fall an easy prey to such influences as may now oppose them. Not only are sanious discharges, pus, and slough quickly reduced to lower terms by the ubiquitous bacterium and its congeners, but decompositions may be effected by the inorganic constituents of the air. The presence of dirt will help to increase the complexity and variety of the changes. The chemical products so generated pass by osmose into the fluids circulating in the tissues, and microzymes whose pabulum these products are gain access to the vessels also, to the general infection of the organism.*

This seems a fitting place to suggest an explanation of the better results which followed the introduction of antisepticism when we compare these results with those of a pre-antiseptic period. Can the improvement have been due in any considerable measure to the germicidal properties of the spray? † The fact that carbolic acid of the strength found least incompatible with the healing process is proved not to be lethal to bacteria, gives an answer in the negative; doubtless, however, the spray would operate in diminishing the activity and germination of bacteria. To what extent the use of germ-proof dressings was favorably instrumental, it is not easy to determine; there are no data having the requisite singleness of meaning. As to the alleged benign influence of carbolic acid upon the chemical exchanges of the tissues and exudations, this may perhaps be neglected—apart from *a priori* considerations—because antiseptics were in general use before the introduction of the spray. It appears to be reasonable to look for the principal causes of antiseptic success in the general cleanliness ob-

* Prof. Burdon Sanderson's Lectures, ibid., passim.

† It will be perceived that an inconsistency is not involved in recognizing this agency; the innocuousness of bacteria we have maintained only for wounded tissues in physiological equilibrium, whereas the spray has been used for the treatment of wounds in various morbid states.

served at every step of Prof. Lister's method, and in the more special kind of cleanliness obtained by the frequent washing away of poisonous exudations, or exudations liable to become poisonous. The tissues are thus protected against two potent sources of physiological disturbance, and in this way, with much likelihood, the antiseptic system has deservingly won the confidence of many eminent surgeons, and not, as often supposed, by having justified the assumption—as to the phlogogenic properties of germs—from whence it issued.

We may now proceed to devise a method or methods of treating wounds based on the data with which biology, physiology, and pathology have equipped us; and in addition to briefly recapitulating as a preliminary, we will vindicate each suggested step by an appeal to those data.

We have seen that the vital processes initiated by the wounding of tissue are of two determinate kinds; a process of disintegration or dissolution, and a process of integration or development. These may be sequent or co-existent in the same wound. We have chosen for exclusive consideration that large class of cases where the processes follow one another, illustrated by the surgically-inflicted, simple, incised wound of normal structures. Here, under natural conditions, there is a definite destruction of tissue succeeded by a definite reconstruction.

The central truths for the practical surgeon which we have endeavored to make clear relate to the source of those actions whose orderly development ends in the organization of cicatricial tissue, and to the conditions determining that development. It has been explicitly set forth in this and the preceding paper, that the repair of wounds is due to the unfolding of physiological powers bequeathed by ancestral organisms, and that, in common with all physiological powers, these in their particular development in the individual are conditioned by agencies of the same kind as those that were present in the circumstances of ancestral life.

We have shown it to be deducible from the conditions of existence, and borne out *a posteriori*, that wounded tissues of

average vitality are in equipoise with an atmosphere possessing average characters.

The corollary has been advanced also, and also inductively corroborated, that common or non-specific bacteria are of themselves incompetent to set up pathological changes, and we have reasoned that when they do so it is *upon some antecedent change of this nature* originally set going by one or more of the chemical and physical actions which usually circumstance the repair of wounds.

We have argued, too, that whatever forces other than those comprised in ordinary air are brought or permitted to come in contact with wounded parts will have the tendency to be in different degrees detrimental to healing. Lastly, the natural coating of the surfaces of a wound by exudative material has been demonstrated to be of high functional value as protecting the exposed cells.

Condensing these several data into a focus of practical conclusions, we have to recognize a class of cases where—*not forgetting the application of admitted principles of physiology and hygiene*—the scientific treatment of wounds will be to intentionally neglect the air as a morbific agent, and to protect the tissues as completely as possible from every *other* chemical or physical influence. Stated in another way, and somewhat less abstractly, knowing the conditions favorable to the healing of wounds, and the conditions unfavorable; as far as the exigencies of practice will permit, our purpose in treatment will be to secure the one set of conditions and avoid or neutralize the other. Whatever method of treatment is adopted, the effects are resultants of forces conducing to repair, and of forces opposing it, and as in other cases are a more or less satisfactory compromise of theory and practice. If a bleeding artery, for instance, demands the application of a ligature we must introduce an element in the conditions which, while averting a greater evil, is obstructive of reparative action directly by its mechanical presence, and indirectly by producing degenerate structures, capable of initiating secondary derangements of function and structure. Or, again, when the position and

nature of a wound necessitate the use of a drainage-tube, to give exit to the deleterious products of tissue necrosis, we choose the lesser of two evils. Further improvement in treatment, therefore, is possible only by making further concessions to the physical and chemical conditions which the nature of things prescribes as indispensable for physiological repair; and the general aim should be, while surrendering as much as possible to these conditions as "theory," to equally respect the claims of practice.

Retaining the provisional conditions stipulated at the outset, let us take an amputation of the thigh as an illustrative case. All surgical instruments—knives, scissors, forceps, drainage-tubes, sutures, etc.—are thoroughly cleansed in warm water and dried before being used. The hands of the operator and assistants, and the cutaneous surface of the part to be operated upon, are in like manner freed from all impurities.

[It has been shown to be inferrible *a priori*, and experience has abundantly proved, that "dirt"—using the word in the broadest sense—is inimical to the healing of wounds. The employment of antiseptics or other drugs for the cleansing of hands or instruments is discountenanced, because it has been conclusively demonstrated that ordinary germs are impotent and sterile in tissues and exudations if these be kept healthy. But healthiness, as here understood, is entirely a matter of molecular grouping, and therefore whatever is prone to disarrange the grouping which is natural—and antiseptics and other drugs are prone to do this—will be liable to lessen the stability of the tissues and exudations to the ever-acting and insensible forces of the medium to which they will be subjected. The hands and instruments are dried for the same reasons.]

As a means for removing blood and clots from the raw surfaces, pieces, two or three inches wide, of old and washed, very dry linen, will, in general, be found eminently efficient. By using this material, rather than sponges or absorbent cotton, a high degree of cleanliness is attained, and the tissues and fluids are kept free from cotton fibres—they remain chem-

ically and physically pure. In cleansing the bleeding points the pieces of linen should be applied with gentleness and without lateral friction. Slight oozing of blood may be disregarded, to avoid undue manipulation of the tissues. As the plasma exudes it must be zealously guarded from every kind of disturbing influence, and be permitted to form a pellicle for the surfaces. A sheet of washed linen, competently arranged for the purpose, will be employed to prevent the bone-dust from falling upon the soft parts.

[We have argued that according to the principles of evolution the exudative blastema must have acquired a special adaptiveness to the more uniform external conditions, and that the inspissation of the blastema, by evaporation of its watery constituents, will help to perfect this adaptiveness. Surgical experience was seen to lend support to the argument.

But this expedient owns a significance and importance that do not lie on the surface, and these must be laid bare and emphasized even at the risk of wearisome repetition.

Life may be profitably thought of as an unceasing conflict between the energies embodied in the tissues of the organism and the energies arrayed against them in the environment, the relative strengths of the contending sides being expressed by the issue, health, disease, or death. But for the greater part this conflict is one of atoms and molecules, not of molar or ponderable parts. Speaking generally, where disease is the resulting event, it is not until the insensibly moving molecules have acquired sufficient momenta to impress their perverted motions upon the masses, that we have any objective evidence of the conflict. And this is just why we fail to see the very beginnings of such morbid changes as erysipelas and septicæmia. They come into visible existence instantaneously; they are under our eyes while we are watching for their approach. The desirability, then, of giving attention to the invisible elements and insensible forces of the body concerned in the inception of disease cannot be gainsaid. If we conserve the powers of the imperceptible units, the perceptible ones may be left to take care of themselves.

Now, as previously pleaded in this connection, the chemical stability of a body—especially if it be an organic body—is, in general, inversely proportional to the mobility of its molecules. We shall at once admit the truth of this if we recollect the qualitative changes wrought by electric vibrations, and by the vibrations of light and heat—which add to the contained motions—and remember how chemical transformations, otherwise impossible, are immediately occasioned by that molecular freedom which solution by fluids gives. The assumption by a liquid, then, of the solid or semi-solid state—as the thickening of plasma on the surfaces of a wound—tells us that its units are taking up more stable positions, and will be less liable to dislodgment by acting forces. When these general considerations are added to the particular one that without water the multiplication and activity is in abeyance of those microscopic organisms so potent in the generation and propagation of diseased processes, we shall grant unreservedly that there must be much virtue in dryness, and that inspissation of the plasma cannot but be in the highest sense conservative and prophylactic.

The essential meaning of the word " solution " assists us to realize that the effect of wounding and the effect of putting liquids on the wound are precisely the same in ultimate nature. In the one case there is a solution of continuity of gross and visible parts, a solution of mechanical cohesions ; in the other there is a solution of continuity of molecular and invisible parts, a solution of molecular cohesions ; for by the word solution, as used to denote the physical action of liquids on other bodies, is meant a dissolving or dissolution—mark the significance of the word—of previously aggregated molar or molecular elements. Therefore, if the kind of wounds understood be treated by washing away and dissolving by liquid applications the protoplasm of the superficial layers of cells, and the issuing plasma—whose glazing we have seen to be the first step in reintegration or repair—we are really attempting to bring together the proximate elements of the tissues by separating their ultimate elements ! That wounds are healing every day

under treatment by liquid dressings is not a controverting fact; whether cicatricial tissue is formed depends on the *relation* between the kinds and strengths of the organic actions needed for union, and the kinds and strengths of the actions circumventing the organism. If the organic actions reach the norme, repair may be effected *despite* improper treatment. So the once common practice of exposing the flaps of a wound to the air finds justification in the recondite principles o physical science.]

Bleeding vessels are twisted or compressed.* The substitution of torsion for the ligature has several advantages. With this practice the flap surfaces may be more equably coadapted, a fertile cause of suppuration and secondary infection is obviated, and, consequently, there is less need for the use of drainage-tubes, which we have seen to be only relatively serviceable.

Hemorrhage having ceased, the wound should remain exposed to the air until the surfaces have become glazed with the dried plasma. The edges of the flaps are then brought into perfect coaptation by a sufficient number of metallic sutures, applied without straining or constricting the tissues. The cutaneous surface is again washed and dried, and *special care taken not to allow the cleansing materials to touch the flap borders.* Plaster and every kind of chemical dressing applied directly to the skin *across the line of union* are eschewed, because not called for in practice, and infringing the principle laid down as to the urgency of preserving intact the natural molecular organization of the tissues and fluids. When strapping is employed the edges of the flaps must be protected.

The wound is now covered with a pad of absorbent cotton enveloped in two or three layers of washed linen of fine text-

* "Up to the end of 1874 we have had two hundred consecutive cases of amputation of the thigh, leg, arm, and fore-arm, in which all the arteries have been twisted (one hundred and ten of them having been of the femoral artery), and no case of secondary hemorrhage—indeed, our house-surgeons never expect to be called to cases of secondary hemorrhage, now that torsion is the general practice of the hospital." Bryant's Manual of Practical Surgery, 3d American edition, edited by Dr. John B. Roberts, p. 965.

ure, suitably shaped for the particular case. This dressing satisfies theoretical requirements and has few practical drawbacks. Besides being absorbent and free from chemical and mechanical irritants, it gives uniform elastic pressure, and may be readily shaped and adjusted. Moreover—though the point is of doubtful importance—it serves as an efficient filter, preventing the access of organic germs to the discharges.*

For the rest, the treatment is according to established surgical rule. Unless there are indications for its earlier removal, the dressing is renewed at the end of one week or later.†

Where primary union is expected drainage-tubes should be dispensed with, and in all cases set aside as soon as expedient.

These measures will be applicable in a large number of cases, including most amputations and operations on the abdomen. There remain many other cases where practice will diverge, though still directed by the canons we have propounded. These are where putrefaction has set in, or will probably set in. This division includes contused, lacerated, and punctured wounds, with much destruction of tissue; operative wounds accompanied by copious discharges, especially where the vitality of the tissues is much depressed; and wounds in special situations, requiring continued irrigation and drainage. Here the primary consideration will be the prophylaxis of putrefaction, and the speedy removal of putrefying and putrescible substances; we shall have recourse to some form of antiseptic treatment pending the advent of conditions suitable for dry-dressing.

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* See The Treatment of Wounds, by Sampson Gamgee, F.R.C.S.

† The changing of dressings hardened with dried exudations may not be without inconveniences, but rarely will they be found such as to offset the risks incurred by resorting to softening materials.

It seems worth while to point out a mechanical advantage accruing from the use of dry-dressing. If the layers of washed linen charged with blood and serum were evenly distributed on both sides of the line of union, the contraction of the dressing during the process of drying might assist in approximating the lips of the wound, for the dressing often becomes firmly adherent to the skin. Such action could be utilized unfailingly with a material designed to contract disproportionately in one or two dimensions.

No definite limit, however, can at present be put to the applicability of dry-dressing. There are many facts congruous with the inference suggested by evolutionary principles that *uncontaminated* pus may be less pernicious than we are apt to think, and its mere removal with the causes of its formation may in many cases suffice to restore the normal state.

If we compare the general design of the system of treatment in possession—Prof. Lister's—with that of the system we have differentiated, it appears that while the one seeks to promote the healing of wounds by controlling the *secondary* causes of non-union, the other, with a more comprehensive recognition of the conditioning forces, seeks to promote healing by controlling the *primary* causes of non-union, both by direct interference and by turning to account and strengthening the organisms' innate resources. At the same time there is distinguished a residue of cases where secondary causes are first in point of importance in actual practice.

The discussion may be properly brought to a close by answering the question: In what is this system principally deserving of espousal and trial? In the first place a point of contact is made between this branch of the science and art of surgery and the most generalized division of the science of biology; the method advocated has for its theoretical basis deductions from biological laws formulating some of the deepest truths of our existence. Also, it may be noticed, this union of the special truths of surgery with the general truths of evolution is itself an illustration of the process of evolution in one of its most interesting aspects.*

And if we study, as written in surgical history, the development of the art which is our theme, we find that each progressive step has throughout been along the path we have just trodden. From the age when hemorrhage was arrested by applying red-hot metal plates to the raw surfaces of the flaps, to our own days of refined ligatures and torsion, the mode of advancement has been the same; the intelligent use of a

* See Spencer's Principles of Psychology, vol. i., p. 343.

deepening and widening knowledge of nature's own art, and the forces which govern her operations.

And applying the test of experience, the claims of this method, it must be allowed, are very forcible. The general results of Dr. Borland * and the special results of Mr. Lawson

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* At the Kilmarnock Infirmary, in the treatment of an amputation wound, "the ordinary flap operation being performed, a screw tourniquet is used to prevent hemorrhage. No water or other liquid is applied to the surface; but, while vessels are being ligatured, blood is mopped off by cloth rags. Old shirting is preferred for this purpose, on account of frequent washing having rendered it almost clear of fibres, etc., likely to adhere to the wound. Sponges are not applied. Silk ligatures are used, and in considerable numbers. After all appreciable vessels have been tied, the flaps are kept open until bleeding has entirely ceased, and the whole surface has assumed a glazed appearance from exposure. The wound is then closed by silk sutures, about five-eighths of an inch apart, the ligatures being brought out at the lower angle. Long strips of adhesive plaster are applied between the sutures, and the stump is enveloped in a single layer of lint spread with lard. Some light covering is next put on, and a cotton bandage over all. In two or three days the wound is dressed. . . . Any discharge is cleaned away by cloth rags or by some disinfectant fluid. If the latter is used, the wound is afterward carefully dried, and lint spread with lard again applied. This treatment is repeated daily or every alternate day, until the cicatrix is complete or the patient dismissed."

Comparison of the results obtained by Dr. Borland with those obtained by Prof. Lister and his followers, discloses for Dr. Borland what are summarily described as "the best general results covering a lengthened period of time that have ever been recorded in the history of British Hospital Surgery."

Subjoined are the figures of Dr. Hector Cameron's antiseptic practice—which is of approved excellence—at the Glasgow Royal Infirmary, and those of Dr. Borland's dry-dressing practice at the Kilmarnock Infirmary.

DR. CAMERON'S RESULTS.

In the whole four years	50 deaths	in 1,706 cases,	or 2.9	per cent.
In the past two years	23 "	878 "	" 2.6	"
In the past one year	9 "	505 "	" 1.79	"

DR. BORLAND'S RESULTS.

In the whole 10⅜ years	33 deaths	in 1,429 cases,	or 2.3	per cent.
In the past 4⅜ "	9 "	828 "	" 1.08	"
In the past 2 1/10 "	0 "	421 "	" 0.	"

—British Medical Journal, July 23, 1881.

Tait *—unequalled in the annals of surgery—have been accomplished by therapeutic means *essentially* those which have been put forward for acceptance; and, be it observed, accomplished empirically. Directed by clearly conceived principles which make possible precision and certainty in the practical applications of science, the expectation is raised of still more brilliant results.

In respect of simplicity, practicability, and economy, the method leaves nothing to be desired; and though its practice may involve a liberal expenditure of time, and the exercise of much care, these cannot weigh against the large balance of assured and promised advantages.

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* The actual success of Mr. Lawson Tait—ninety-seven recoveries in one hundred consecutive cases of ovariotomy—has already been incidentally mentioned and is widely known. This success is attributed among other conspiring circumstances to the "complete abandonment of the use of carbolic acid or any other (so-called) antiseptic system, in the performance of the operation and in the subsequent treatment."—British Medical Journal, October 28, 1882.

"All of these cases were dressed with dry absorbent cotton-wool; in about one-twentieth of the cases a part of the wound opened, and then it was dressed with zinc ointment or red lotion."—New York Medical Record, September 9, 1882.

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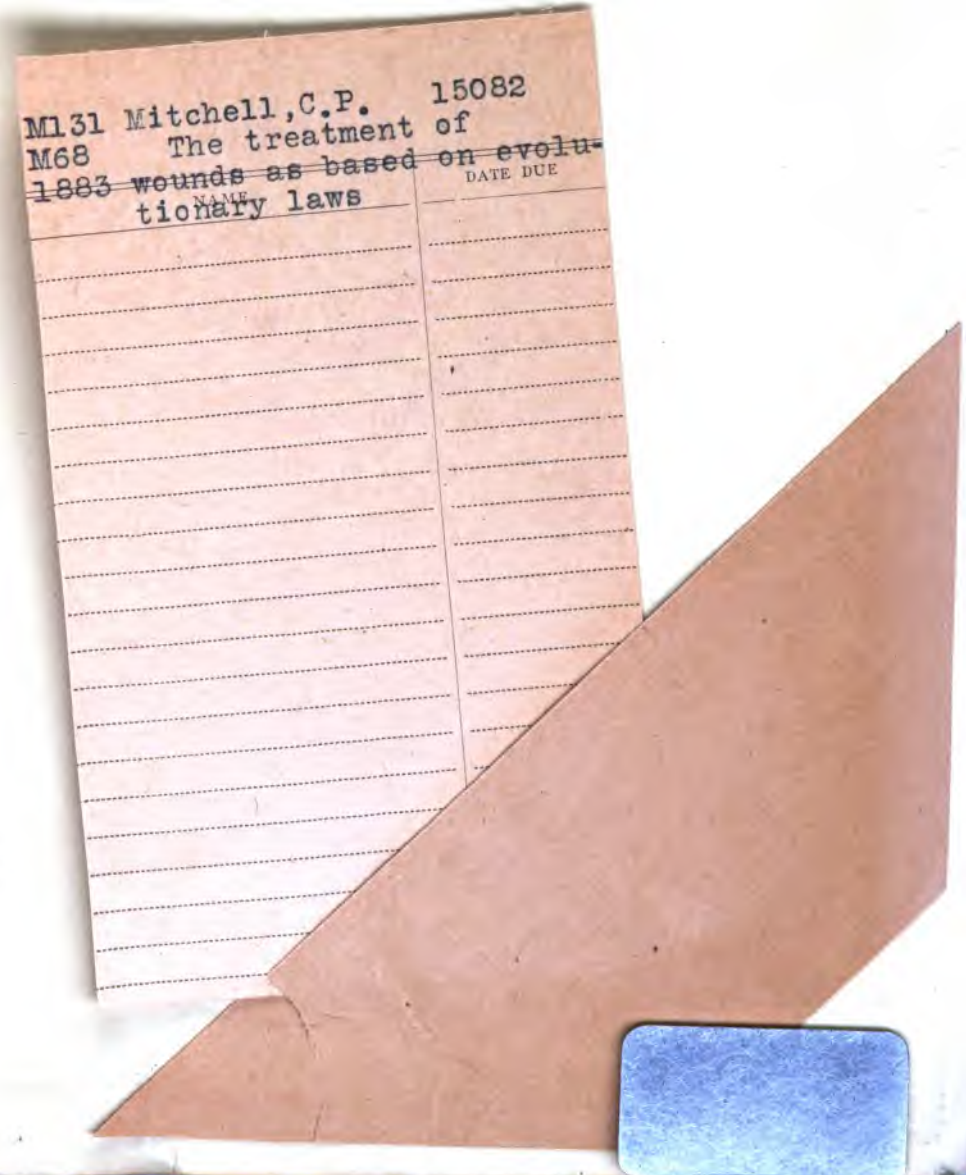
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